Determining the effects of aqueous alteration on the distribution of oxygen isotopes in carbonaceous chondrites

Conference or Workshop Item

DETERMINING THE EFFECTS OF AQUEOUS ALTERATION ON THE DISTRIBUTION OF OXYGEN ISOTOPES IN CARBONACEOUS CHONDRITES. A. A. Morris, L. Baker, I.A. Franchi and I.P. Wright. Planetary and Space Science Research Institute, The Open University, Milton Keynes, MK7 6AA (a.a.morris@open.ac.uk)

Introduction: Carbonaceous chondrites play a key role in determining the history of the early Solar System; a knowledge of the oxygen isotope variation within these materials will not only help in our understanding of the origin and evolution of those meteorites, but also the early Solar System reservoirs from which they formed [1].

However, several problems present themselves when trying to interpret early Solar System history. One is identifying the isotopic signature of oxygen from specific component compounds in a complex mixture of materials that existed in the solar nebula, and deconvoluting this from signatures developed during parent body processing (e.g. aqueous alteration, thermal metamorphism). Only then is it possible to develop an understanding of the nature and conditions of these secondary processes.

Background: Of all the meteorite groups the carbonaceous chondrites (particularly the CI, CM and CR meteorites) have the most diverse range of high and low temperature mineral phases, and display the widest range of oxygen-isotopic compositions [1,2]. Volumetrically, much of these meteorites consists of a very fine grained matrix material composed largely of low temperature alteration minerals but intimately mixed with a fine grained fraction of the anhydrous, isotopically distinct phases [3]. A full understanding of the oxygen-isotopic systematics between these different phases is required in order to constrain the processes that led to their formation [3]. However most previous oxygen isotope studies have concentrated on the silicate portions which in the case of the matrix means studying complex mixtures [3,4]. Aqueous reactions can not only promote chemical redistribution and changes in petrological relationships but also generate large isotopic fractionation of oxygen isotopes [5].

Models to account for the variations in oxygen-isotopic compositions in carbonaceous chondrites e.g. [6,7] generally involve mixing of a solid anhydrous silicate component, with an isotopic composition enriched in ^{16}O, with liquid water depleted in ^{16}O along with mass-dependent isotopic fraction between various phases at low temperature [3]. Isotopic evolution of the fluids involved in these reactions would be expected to lead to significant isotopic heterogeneity within the components e.g. [7].

Recent studies have shown that structural water $(OH)^-$ can be extracted from phyllosilicate components in the CM meteorites by incremental heating, and used for oxygen isotope measurements. This also provides the ability to resolve oxygen from a number of different components within the complex mixture of minerals in the matrix of these meteorites[3,4]. The $(OH)^-$ from the CM phyllosilicates is found to have a similar $\Delta^{17}O$ to co-existing carbonates, analysed by [8] indicating that they formed from the same fluid reservoir, and may infact have formed in isotopic equilibrium.

We are employing a number of approaches to better determine the distribution of oxygen isotopic components within these complex meteorites. Stepped heating extraction to liberate water and structural $(OH)^-$ permits isotopic measurements of resolved components [4], the identification of which is being established by a detailed study of the thermal release temperature of water $(OH)^-$ components from meteorites and a range of terrestrial analogues. Artifical weathering experiments using isotopically labeled water are being used to trace the location of different oxygen reservoirs as alteration proceeds.

Such data may then be used to constrain temperature of equilibrium between the phyllosilicates and carbonates minerals and water-rock ratios involved; important constraints for evolution models of carbonaceous chondrites [6,7].

Summary: The initial stepped heating experiments for carbonaceous chondrites revealed considerable variation in $\delta^{18}O$ [3]. Much of our new work is aimed at determining the extent of isotopic fractionation associated with the formation of the common phyllosilicates found in meteorites, and identifying the specific minerals liberating $(OH)^-$ at each temperature.

This will be used ultimately to better constrain the isotopic composition of the fluids involved in the alteration process.

[1] Clayton R. N. & Mayeda T. K. (1999) *GCA, 63,* 2089–2104. **[2]** Brearley A. J. & Jones R. H. (1998) *Planetary Materials, 36,* 3-01-3-370. **[3]** Franchi. *et al* (2001) *Phil. Trans. R. Soc. Lond. A 359,* 2019–2035. **[4]** Baker. *et al*. (2002) *Analyl. Chem. 74* 1665-1673 . **[5]** Zolensky M. & McSween H. Y. (1988) *Meteorites and the Early Solar System,* 114-144. **[6]** Clayton R. N. & Mayeda T. K. (1984) *EPSL*, 67, 151-161. **[7]** Young E. D. *et al*. (1999) *Science*, *286,* 452-455. **[8]** Benedix. *et al*. (2000) *LPSC XXX1* Abs #1840